FISHERY DATA SERIES NO. 27

NORTHERN PIKE ABUNDANCE AND COMPOSITION STUDY

By: Richard Peckham and
David R. Bernard

STATE OF ALASKA
Steve Cowper, Governor
ALASKA DEPARTMENT OF FISH AND GAME
Don W. Collinsworth, Commissioner
DIVISION OF SPORT FISH
Norval Netsch, Director

P.O. Box 3-2000, Juneau, Alaska 99802

OCTOBER 1987

NORTHERN PIKE ABUNDANCE AND COMPOSITION STUDY[1]

By Richard Peckham and
David R. Bernard

October 1987

ALASKA DEPARTMENT OF FISH AND GAME
Division of Sport Fish
Juneau, Alaska 99802

[1]This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-2, Job Number N-8-2.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF APPENDIX TABLES

ABSTRACT

Northern Pike (*Esox lucius* Linnaeus) populations in Volkmar, Tee, and George Lakes near Delta Junction, Alaska were sampled in 1986 with gill nets, trap nets, and seines. Estimates of abundance from Petersen mark-recapture experiments were 4,026 and 454 northern pike ≥ 450 millimeter fork length in Volkmar and Tee Lakes, respectively. Analysis of tag returns indicated that gill nets caught larger northern pike while trap nets and seines caught the same-sized northern pike, but smaller fish than those caught in gill nets. Gill nets were demonstrably selective for larger fish. Catchability coefficients for panels of different mesh sizes in experimental gill nets were calculated for Volkmar and Tee Lakes. Parameters for length-weight, length-at-age, and weight-at-age relationships were estimated for data collected in 1986 and in previous years. Estimates of sex composition and average growth by individual fish are given. More northern pike were captured in seines and released alive than were caught and released alive in either gill nets or trap nets. Capture rates of northern pike dropped dramatically for all gears after early June.

KEY WORDS: Northern pike, *Esox lucius*, Volkmar Lake, Tee Lake, George Lake, Alaska, trap nets, gill nets, seines, catchability coefficients, gear selectivity, abundance, mark-recapture, gear assessment, growth, length-weight, length-at-age, weight-at-age, sex ratios.

INTRODUCTION

The popularity of northern pike (*Esox lucius* Linnaeus) as a sport fish in Alaska has increased in recent years. Next to Arctic grayling (*Thymallus arcticus* Pallas) the northern pike is the most sought-after, indigenous sport fish species in interior Alaska. From 1977 to 1984, the estimated annual statewide harvest of northern pike increased from 11,982 to 18,641, reaching a high of 21,476 in 1983 (Mills 1986). The Arctic-Yukon-Kuskokwim (A-Y-K) Region accounted for 76% of the estimated harvest of northern pike in 1984 and 90% for 1977-1984. Waters in the Tanana River drainage are the most accessible in the A-Y-K Region and provided 64% of the total recreational harvest of northern pike for that region for the same eight-year period. Three of the most popular sport-fishing waters in the region are George and Volkmar Lakes and Minto Flats.

Stock assessment and creel census at George and Volkmar Lakes were conducted from 1971-1984 (Peckham 1972-1985) (Figure 1). Research on Volkmar Lake in 1985 (Peckham 1986) provides the first estimate of abundance of a northern pike population in Alaska. Over 1,200 northern pike were sampled, of which about 1,000 were tagged or approximately 25% of the population of northern pike over 450 mm in fork length (FL). Estimates of biomass for fish 450 mm FL and greater were presented, along with findings on Catch Per Unit of Effort (CPUE), length frequency, age and growth, and sex composition. Juvenile northern pike were also sampled to get information on their size and age.

Volkmar Lake (273 ha; 675 acres) has two small inlets and an ill-defined outlet which drains westerly into the flats toward the Goodpaster River. Maximum depth is 12.8 m (42 ft). The lake is usually ice-free from late May to early October. Other fish species present include humpback whitefish (*Coregonus pidschian* Gmelin), least cisco (*Coregonus sardinella* Valenciennes), and slimy sculpin (*Cottus cognatus* Richardson). The popularity of Volkmar Lake, particularly for winter fishing, is growing because of recent land disposals around the lake by the State, because of improved winter access from new roads in the Delta Agricultural Project, and because of increased winter use by cabin owners on the nearby Goodpaster River.

George Lake (1,823 ha; 4,500 acres) has one major inlet (navigable by boat in its lower portion), six smaller inlets, and a single, navigable outlet (George Creek) to the Tanana River approximately 8 km (five miles) to the west. Maximum depth is 11.0 m (36 ft). The lake usually becomes ice free about one week later than Volkmar and Tee Lakes. Other fish species present (besides northern pike) include humpback whitefish, least cisco, longnose suckers (*Catostomus catostomus* Forster), burbot (*Lota lota* Linnaeus), and slimy sculpin. Arctic grayling and round whitefish (*Prosopium cylindraceum* Pallas), although uncommon, are occasionally captured in the lake.

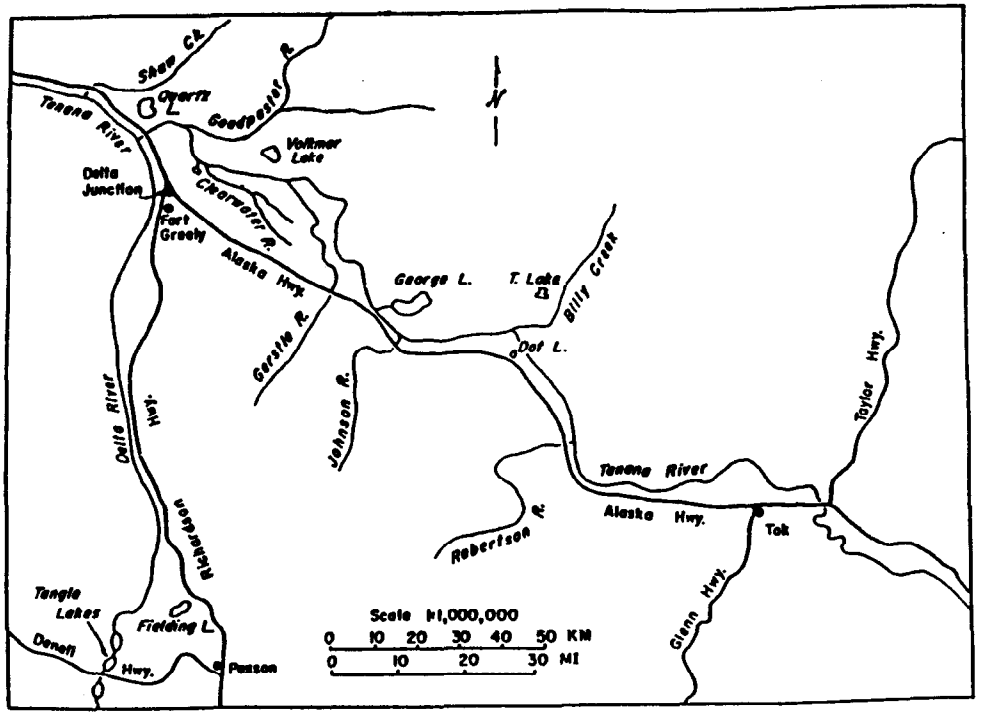

Figure 1. Location of George, Volkmar, and Tee Lakes, Alaska.

Tee Lake (158 ha; 390 acres) has one small inlet and an outlet that flows from the northeast corner of the lake into Billy Creek (Figure 1). Maximum depth is 17.4 m (57 ft). The outlet is intermittent, flowing primarily during June following spring melt. The ice-free period is very similar to that of Volkmar Lake. Fish species present include northern pike, humpback whitefish, least cisco, and burbot.

The goal of this project is the assessment of important stocks of northern pike and the investigation of the biology of these populations relevant to management of sport fisheries on them. The objectives for 1986 were to:

1) estimate the abundance of northern pike in Volkmar and Tee Lakes;

2) estimate indices of the catch per unit of effort for gill nets used in Volkmar and Tee Lakes;

3) estimate the sex composition and the length-weight, age-length, and age-weight relationships of northern pike sampled in Volkmar, Tee, and George Lakes; and,

4) assess seines, trap nets, and gill nets as a means of sampling northern pike in George and Volkmar Lakes.

METHODS AND MATERIALS

Abundance was estimated in Volkmar and Tee Lakes with mark-recapture experiments using the Chapman modification of the Petersen estimator described by Ricker (1975). Floating and sinking variable mesh gill nets were used to capture northern pike during both the marking and recapture events in both lakes. Also, trap nets and seines were used to capture northern pike in Volkmar Lake during the recapture event. Nets were set or pulled perpendicularly to the shoreline near shore or at the outer fringes of emergent vegetation. Gill nets were continuously monitored and fish were removed carefully to minimize sampling mortality. Panel of capture was noted for each fish caught in gill nets. Tee Lake was divided into two sections, and section of release and recapture was recorded for each fish.

To assess alternate capture gear for northern pike, gill nets, seines, and trap nets were used on George Lake and during the recapture event on Volkmar Lake. A description of the various gear types used is provided in Table 1. The configuration of various trap-net sets used is shown in Figure 2. Comparison of performance among gears was based on CPUE of northern pike, size selectivity for northern pike, and on the mortality rate of captured fish.

Fork lengths of fish were measured to the nearest millimeter. Weights were measured to the nearest 10 g on a Chatillon IN-6 or IN-25 spring scale. Fish were tagged with Floy FD-68 anchor tags. Each fish was inspected to find sexual products or the external characteristics described by Casselman (1974) as indications of sex.

Table 1. Descriptions of the gear used to capture northern pike in George, Volkmar, and Tee Lakes in 1986.

Gear Type	Description
Gill Nets:	
1) Five panel (floating)	38 m (125 ft) long with 7.6 m (25 ft) panels of 25 mm (1.0 in), 38 mm (1.5 in), 51 mm (2.0 in), 64 mm (2.5 in) and 76 mm (3.0 in) bar mesh multifilament netting.
2) Six panel (floating and sinking)	46 m (150 ft) long with 7.6 m panels of 25, 38, 51, 25, 38, and 51 mm bar mesh multifilament netting.
Traps:	
1) Hoop traps	1 m (3 ft) diameter by 4 m (12 ft) long with 25 mm square mesh nylon netting on 7 fiberglass hoops and with finger-style throats on second and fourth hoops. Attached leads and wings were of various depths of from 1.3 m (4 ft) to 3.3 m (10 ft) with mesh sizes of 10 or 25 mm.
Seines:	
1) 100 ft bag seine	30 m (100 ft) long by 3 m (10 ft) deep with 25 mm square mesh
2) 100 ft bagless seine	30 m long by 4.3 m (14 ft) deep with 25 mm square mesh.
3) 220 ft bag seine	Same as 30 m bag seine with an 18 m (60 ft) extension added to each end.

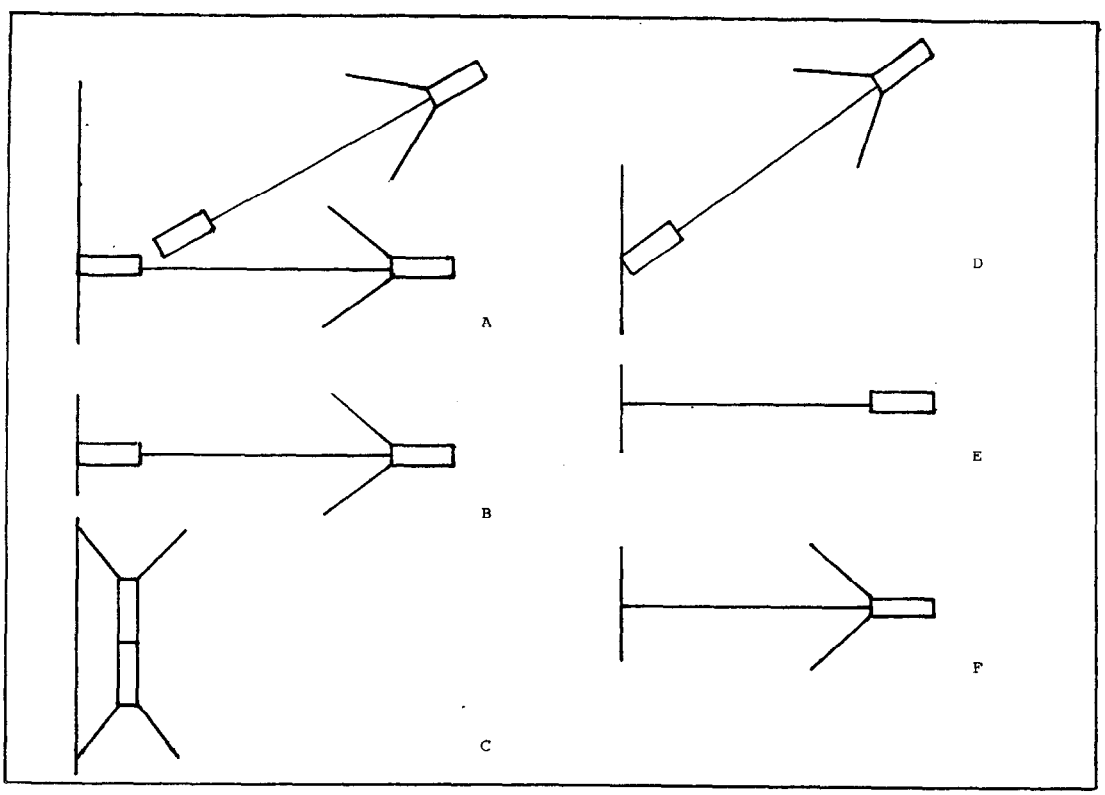

Figure 2. Schematic diagram of the different sets of trap nets used in George and Volkmar Lakes, 1986.

Because an analysis of scales, vertebra, and cleithra showed all three structures give, on average, the same ages for northern pike in Alaska (see Appendix Table 1), scales were used to estimate the ages of northern pike. Scale samples were removed from each fish just forward of a vertical line at the anterior margin of the dorsal fin midway between the fin and the lateral line. Scales were cleaned and mounted between glass slides or on gummed cards, then impressed on 20 mil acetate using a Carver Press at 60,000 kg/cm^2 (20,000 psi) heated to 93°C (200°F) for 30 seconds and read along their dorsal radius on a 3M Consultant 114 Microfiche reader.

The length-weight and age-length relationships of northern pike were described with allometric and von Bertalanffy models, respectively. Parameters for both models were estimated with an iterative computer program based on the Marquardt algorithm (Marquardt 1960). The solution for each set of parameters was the set of estimates that minimized the least-squared differences between the predicted model and observed values. Each solution was based on a range of initial values for parameters with each set of values producing an "answer" from which the solution was chosen according to the least-squares criterion. The sets of initial values for the age-length models were all possible combinations of the values for "a" (0.0, 0.2, 0.4, 0.6, 0.8, 1.0, 1.2, 1.4, 1.6, 1.8, and 2.0), for "b" (same values as for "a"), and for "c" (-2.0, -1.6, -1.2, -0.8, -0.4, 0.0, 0.4, 0.8, 1.2, 1.6, and 2.0). The sets of initial values for the length-weight models were all possible combinations of the values for "a" (2, 4, 6, 8, and 10) and for "b" (2.0, 2.2, 2.4, 2.6, 2.8, 3.0, 3.2, 3.4, 3.6, 3.8, and 4.0).

Catchability coefficients for gill nets were estimated as functions of catch per unit of effort and abundance according to equations in Hamley (1975):

$$1) \qquad q = \overline{CPUE}/\hat{N}$$

where;

q = the catchability coefficient;

$\overline{CPUE}$ = mean catch per unit of effort; and,

$\hat{N}$ = estimated abundance.

Gill nets were positioned along the shore of each lake as mentioned above, then were inspected in rotation with captured fish removed and processed during each visit. Catch per unit of effort as an index of abundance was calculated as the ratio of the catch during each full cycle of the rotation:

2) $$CPUE_{ijk} = C_{ijk}/h_{ijk}$$

where;

C = catch;

h = hours since last inspection of the net;

i = mesh size;

j = fish size, and;

k = set number.

A set was an interval of time between consecutive visits to each gill net whether the net had been moved or not. Because gill nets are noted for their different selectivity for fish of different sizes, average CPUE was calculated for each mesh size (panel) in the variable mesh gill nets (25, 38, 51, 64, and 76 mm meshes). Average CPUE and its variance were calculated according to jackknife procedures of Efron (1982) for each mesh size in both five- and six-panel nets. Since five-panel gill nets had but one panel of each mesh size while six-panel nets had two for most mesh sizes (Table 1), the overall averages of CPUE for mesh sizes of 25, 38, and 51 mm were weighted averages of the means for each type of gill nets:

3) $$\overline{\overline{CPUE}}_{ij} = \frac{H_5\overline{CPUE}_{ij(5\text{-panel})} + \frac{H_6}{2}\overline{CPUE}_{ij(6\text{-panel})}}{H_5 + H_6/2}$$

where;

H = the number of hours fished with five- or six-panel nets during the first sampling event.

The hours fished with the six-panel nets were halved because each such net had two panels for each mesh size while the five-panel nets had but one. The variances for the overall means were calculated as:

4) $$V[\overline{\overline{CPUE}}_{ij}] = \frac{H_5^2 V[\overline{CPUE}_{ij(5\text{-panel})}] + \frac{H_6^2}{4} V[\overline{CPUE}_{ij(6\text{-panel})}]}{(H_5 + H_6/2)^2}$$

The approximate variance for q was then calculated according to the delta method:

$$5) \quad V[q] \approx \frac{\overline{CPUE}^2}{\hat{N}^2} \left\{ V[\overline{CPUE}]/\overline{CPUE}^2 + V[\hat{N}]/\hat{N}^2 \right\}$$

Because the abundance estimates from the Petersen method are relevant to the first sampling event, the catchability coefficients were based on the CPUE information obtained only during the first event.

RESULTS

Population Abundance

Volkmar Lake:

Abundance of northern pike was estimated for the second consecutive year in Volkmar Lake in June 1986. A total of 820 northern pike was marked during the first sampling event from 3-6 June; 448 were captured during the second sampling event from 16-19 June. Two estimates of abundance were made on Volkmar Lake, one based on data from gill nets and the other based on data from traps and seines. Contingency table analysis showed that the size-selectivity of these three gears were significantly different ($\chi^2 = 50.37$, df = 6, $P < 0.001$; see Appendix Table 2). Further tests showed that gill nets caught larger fish than did trap nets or seines while trap nets and seines caught fish of the same sizes.

For the first estimate, abundance was calculated for three size groups: 1) $\leq$ 449 mm FL, N = 4,027; 2) 450-749 mm FL, N = 3,890; and 3) $\geq$ 750 mm FL, N = 136 (Table 2). Analysis of tag returns indicated that gill nets were selective for larger fish ($\chi^2 = 10.24$, df = 2, $0.005 < P < 0.01$) and that the categories above are the optimal division to adjust for this selectivity (see Appendix Table 3). Therefore, the first estimate for all northern pike $\geq$ 450 mm FL in Volkmar Lake was 4,026.

The second estimate (Table 3) is based on data from trap nets and seines and was 3,997 northern pike $\geq$ 450 mm FL. There is no subdivision of this estimate by size group because trap nets and seines were presumed not to be size selective. Fish recaptured in trap nets and seines were too few to test hypotheses of equal selectivity with the groups listed above. However, tests on different size groups $\leq$ 549 mm Fl and $\geq$ 550 mm FL showed nonsignificant differences in proportions of marked fish recaptured ($\chi^2 = 0.9$, df = 1, $0.25 < P < 0.5$).

As shown in Tables 2 and 3, the sampling rates dropped dramatically between sampling events for fish of all sizes captured with gill nets. It should be noted that the sampling rate for the first event was a minimum estimate because mortalities from netting and handling were not released as marked fish.

Table 2. Estimated abundance of northern pike based on fish sampled with gill nets in Volkmar Lake, 3-6 June and 16-19 June 1986.[1]

	Number					Sampling Rate at each Event	
mm FL	Marked	Recaptured	Examined	Estimate	SE	First	Second
300-449	151	1	52	4,027	2,266		
450-749	782	32	163	3,890	584	20.1%	4.1%
≥750	38	1	6	136	65	28.0%	2.6%
Total > 450				4,026	587		

[1] The estimates pertain to the population present at the time of the first sampling event.

Table 3. Estimated abundance of northern pike in Volkmar Lake based on fish sampled with gill nets 3-6 June 1986, and trap nets and seines 16-19 June 1986.[1,2]

mm FL	Number Marked	Number Recaptured	Number Examined	Estimate	SE
300-449	151	4	116	3,556	1,397
≥450	820	22	111	3,997	717

[1] The estimates pertain to the population present at the time of the first sampling event.

[2] No comparison of sampling rates between sampling events are listed because different gear were used for each event.

Tee Lake:

Sampling of fish on Tee Lake was accomplished solely with gill nets and occurred on 30 May-1 June and on 11-13 June. Abundance was estimated for two size groups as follows (Table 4): 1) 450-749 mm FL, N = 412; and 2) $\geq$ 750 mm FL, N = 42. The combined estimate of all northern pike $\geq$ 450 mm FL was 454. Abundance of fish $\leq$ 449 mm FL was not estimated because only 18 fish in this size category were captured in the first event and no marked recaptures were captured during the second event. Like Volkmar Lake, analysis of tag returns indicated that gill nets were selective for larger fish (χ^2 = 12.06, df = 3, 0.005 < P < 0.01) and that the two size categories were the optimal division to adjust for this selectivity (see Appendix Table 4).

As shown in Table 4, the sampling rate dropped off between events in Tee Lake as it did in Volkmar Lake (Table 2), although not as greatly. However, in Tee Lake the decrease in sampling rate was more pronounced for medium size fish (450-749 mm FL).

A statistical test was conducted to determine if tagged fish had completely mixed with untagged fish in Tee Lake. The hypothesis tested was that a recovered fish had an equal probability of being captured in either half of the lake regardless of where it was released. Differences in recovery rates proved not significant (χ^2 = 3.58, df = 2, 0.10 < P < 0.25), and we concluded tagged fish had mixed with untagged fish, just as the Petersen method requires (see Appendix Table 5).

Catch Rates

Differences in CPUE for populations in Volkmar and Tee Lakes clearly demonstrated that each type of gill net used was size selective toward medium (450-749 mm FL) and large ($\geq$ 750 mm FL) fish (Tables 5 and 6). While the estimates of abundance on Volkmar Lake (reported previously) showed nearly equal numbers of fish larger and smaller than 450 mm FL, the CPUE was much greater for fish larger than 450 mm.

Data for populations in Volkmar and Tee Lakes also showed higher CPUE with the six-panel nets than with the five-panel nets, while CPUE for sinking six-panel and floating six-panel nets in each lake were similar. For the population in Volkmar Lake, the combined CPUE for all sizes for sinking six-panel nets was 1.89 fish per hour and for floating six-panel nets was 2.01 (Table 5). For the population in Tee Lake, the combined CPUE for all size groups for sinking six-panel nets was 1.29 and for floating six-panel nets was 1.13 (Table 6).

Table 4. Estimated abundance of northern pike based on fish sampled with gill nets in Tee Lake, 30 May-1 June and 11-13 June 1986.[1]

	Number					Sampling Rate at each Event	
mm FL	Marked	Recaptured	Examined	Estimate	SE	First	Second
300-449	18	0	10				
450-749	232	43	77	412	37	56.3%	18.5%
≥750	27	12	19	42	5	64.2%	44.4%
Total (≥450)				454	42		

[1] The estimates pertain to the population present at the time of the first sampling event.

Table 5. Catch Per Unit of Effort (CPUE) of small, medium-sized, and large northern pike in variable mesh gill nets during the first sampling event in Volkmar Lake in 1986.[1]

		< 450 mm		450-749 mm		> 749 mm		All Lengths	
Date	Hours	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
Sinking Six-panel									
3 June	67.7	16	0.24	113	1.67	4	0.06	133	1.96
4 June	74.4	12	0.16	85	1.14	3	0.04	100	1.34
5 June	74.5	29	0.39	121	1.62	4	0.05	154	2.07
6 June	71.7	37	0.52	115	1.6	5	0.07	157	2.19
All	288.3	94	0.33	434	1.51	16	0.06	544	1.89
Floating Six-panel									
3 June	43.2	8	0.19	48	1.11	2	0.05	58	1.34
4 June	70.3	17	0.24	113	1.61	8	0.11	138	1.96
5 June	63.1	14	0.22	84	1.33	5	0.08	103	1.63
6 June	68.6	27	0.39	167	2.43	1	0.01	195	2.84
All	245.2	66	0.27	412	1.68	16	0.07	494	2.01
Floating Five-panel									
4 June	40.5	5	0.12	26	0.64	6	0.15	37	0.91
5 June	39.2	7	0.18	50	1.28	6	0.15	64	1.63
All	79.7	12	0.15	76	0.95	12	0.15	101	1.27

[1] Few fish were caught during the second sampling event so only data from the first event are reported in this table. A detailed description of nets is provided in Table 1.

Table 6. Catch Per Unit of Effort (CPUE) of small, medium-sized, and large northern pike in experimental mesh gill nets during the first sampling event in Tee Lake in 1986.[1]

		< 450 mm		450-749 mm		> 749 mm		All Lengths	
Date	Hours	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
Sinking Six Panel									
30 May	27.4	2	0.07	39	1.42	3	0.11	44	1.61
31 May	33.6	5	0.15	35	1.04	2	0.06	42	1.25
1 June	60.2	5	0.08	58	0.96	7	0.12	70	1.16
All	121.2	12	0.10	132	1.09	12	0.10	156	1.29
Floating Six-panel									
30 May	39.8	1	0.03	50	1.26	7	0.18	58	1.46
31 May	44.7	3	0.07	19	0.43	3	0.06	25	0.59
1 June	83.8	5	0.06	85	1.01	12	0.14	102	1.27
All	168.3	9	0.05	155	0.91	22	0.13	185	1.08
Floating Five-panel									
31 May	5.6	0		4	0.71	2	0.61	6	1.07

[1] Few fish were caught during the second sampling event so only data from the first event are reported in this table. A detailed description of nets is provided in Table 1.

For the population of northern pike in George Lake, CPUE for sinking six-panel gill nets were much higher than for the other two lakes, however, the number of net hours was small (4.1). Catch per unit of effort for northern pike 450-749 mm FL was 5.85 fish per hour and for all sizes combined was 7.27 (Table 7). Floating six-panel gill nets caught northern pike < 450 mm FL at a rate of 1.52 fish per hour, but again few hours of fishing were involved.

Average CPUE and catchability coefficients (q) for small, medium, and large northern pike by mesh size in five- and six-panel gill nets fished in Volkmar and Tee Lakes indicated a range of values. Because floating and sinking gill nets caught northern pike with near equal frequency, no distinction along these lines was made in calculating the statistics (Tables 8 and 9). In Volkmar Lake, (Table 8) panels of 25 mm mesh were about equally selective for fish of all sizes although the catchability was low. As mesh size increased to 38 mm, catchability of medium-sized and large fish, especially the former, increased also. As mesh size increased further to 51 mm, catchability of large fish tripled while catchability of small fish dropped by about an order of magnitude; catchability of medium-sized fish remained about the same. And, as mesh size reached 64 mm, only the large fish were caught with any regularity.

This progression of catchability for Volkmar Lake was repeated in the statistics for Tee Lake, except medium-sized fish had a higher catchability coefficient in panels with 25 mm mesh than did fish of other sizes. Catchability coefficients were generally higher in Tee Lake than in Volkmar Lake. No northern pike were caught in the panels with 76 mm mesh in either lake. Standard errors for average CPUE and catchability coefficients are presented in Appendix Tables 6 and 7.

Life History

Length-Weight Relationship:

Comparison of the estimated parameters in length-weight relationships shows that northern pike were heaviest at length in Tee Lake with fish from Volkmar Lake slightly less so; and, with northern pike in George Lake the least robust (Figure 3). These parameter estimates were based upon data collected in 1986 only. Inspection of plots showed no significant differences in the length-weight relationships for males and females in any lake. Parameters were estimated for data collected in George Lake from 1972-1981 ($a = 6.27176$, $SE(a) = 0.13990$; $b = 2.8999$, $SE(b) = 0.05273$; $Corr(a,b) = 0.8335$; $n = 356$).

Length-At-Age Relationship:

Ages were determined for 774 northern pike sampled from Volkmar Lake in 1985 and 1986, 71 from Tee Lake in 1986, and 1,457 from George Lake in 1972, 1974-76, 1979-81, and 1986. The oldest female from Volkmar Lake was 14 years, while 13 years was the oldest for both George and Tee Lakes. A single male from Volkmar Lake was aged at 13 years, while in Tee and George

Table 7. Catch Per Unit of Effort (CPUE) of small, medium-sized, and large northern pike in experimental mesh gill nets during the first sampling event in George Lake in 1986.[1]

		< 450 mm		450-749 mm		> 749 mm		All Lengths	
Date	Hours	No.	CPUE	No.	CPUE	No.	CPUE	No.	CPUE
Sinking Six-panel									
12 June	4.1	7	1.71	24	5.85	1	0.24	32	7.27
Floating Six-panel									
12 June	3.3	5	1.52	1	0.30	1	0.30	7	2.12

[1] Few fish were caught during the second sampling event so only data from the first event are reported in this table. A detailed description of nets is presented in Table 1.

Table 8. Average Catch Per Unit of Effort (CPUE) and catchability coefficients (q) by panel in five- and six-panel gill nets fished in Volkmar Lake for northern pike 3-6 June 1986.[1,2]

	25 mm mesh			38 mm mesh			
	Small[3]	Medium	Large	Small	Medium	Large	Hours Fished
5-Panel	0.146	0.074	0.000	0.000	0.294	0.011	84.7
6-Panel	0.124	0.137	0.007	0.157	1.022	0.020	533.5
$\overline{\text{CPUE}}$	0.129	0.122	0.006	0.119	0.847	0.018	351.5
$qx10^5$	3.639	3.135	4.146	3.341	21.766	12.950	

	51 mm mesh			64 mm mesh			
	Small	Medium	Large	Small	Medium	Large	Hours Fished
5-Panel	0.000	0.429	0.029	0.014	0.046	0.098	84.7
6-Panel	0.009	0.663	0.052				533.5
$\overline{\text{CPUE}}$	0.007	0.607	0.046	0.014	0.046	0.098	351.5[4]
$qx10^5$	0.194	15.599	34.045	0.397	1.182	72.235	

[1] Standard errors for these estimates are in Appendix Table 6.

[2] All five-panel nets were floating gill nets; six-panel nets were both sinking and floating.

[3] Small fish were shorter than 450 mm FL, medium fish were 450-749 mm FL, and large fish were longer than 749 mm FL.

[4] The hours for the six-panel nets were halved from 533.5 to 266.75 for the weights because each hour that one of these nets was fished, two panels of each mesh size were in the water.

Table 9. Average Catch Per Unit of Effort (CPUE) and catchability coefficients (q) by panel in five- and six-panel gill nets fished in Tee Lake for northern pike 30 May-1 June 1986.[1,2]

	25 mm mesh			38 mm mesh			
	Small	Medium	Large	Small	Medium	Large	Hours Fished
5-Panel	0.000	0.099	0.000	0.000	0.037	0.000	5.6
6-Panel	0.029	0.082	0.003	0.030	0.334	0.027	289.5
$\overline{\text{CPUE}}$	0.027	0.083	0.003	0.028	0.323	0.026	150.4[3]
$qx10^5$		20.120	6.974		78.403	61.910	

	51 mm mesh			64 mm mesh			
	Small	Medium	Large	Small	Medium	Large	Hours Fished
5-Panel	0.000	0.010	0.010	0.000	0.000	0.010	5.6
6-Panel	0.002	0.349	0.061				289.5
$\overline{\text{CPUE}}$	0.002	0.336	0.059			0.010	150.4[4]
$qx10^5$		81.553	140.476			23.810	

[1] Standard errors for these estimates are in Appendix Table 7.

[2] All five-panel nets were floating gill nets; six-panel nets were both sinking and floating.

[3] Small fish were shorter than 450 mm FL, medium fish were 450-749 mm FL, and large fish were longer than 749 mm FL.

[4] The hours for the six-panel nets were halved from 289.5 to 144.8 for the weights because each hour that one of these nets was fished, two panels of each mesh size were in the water.

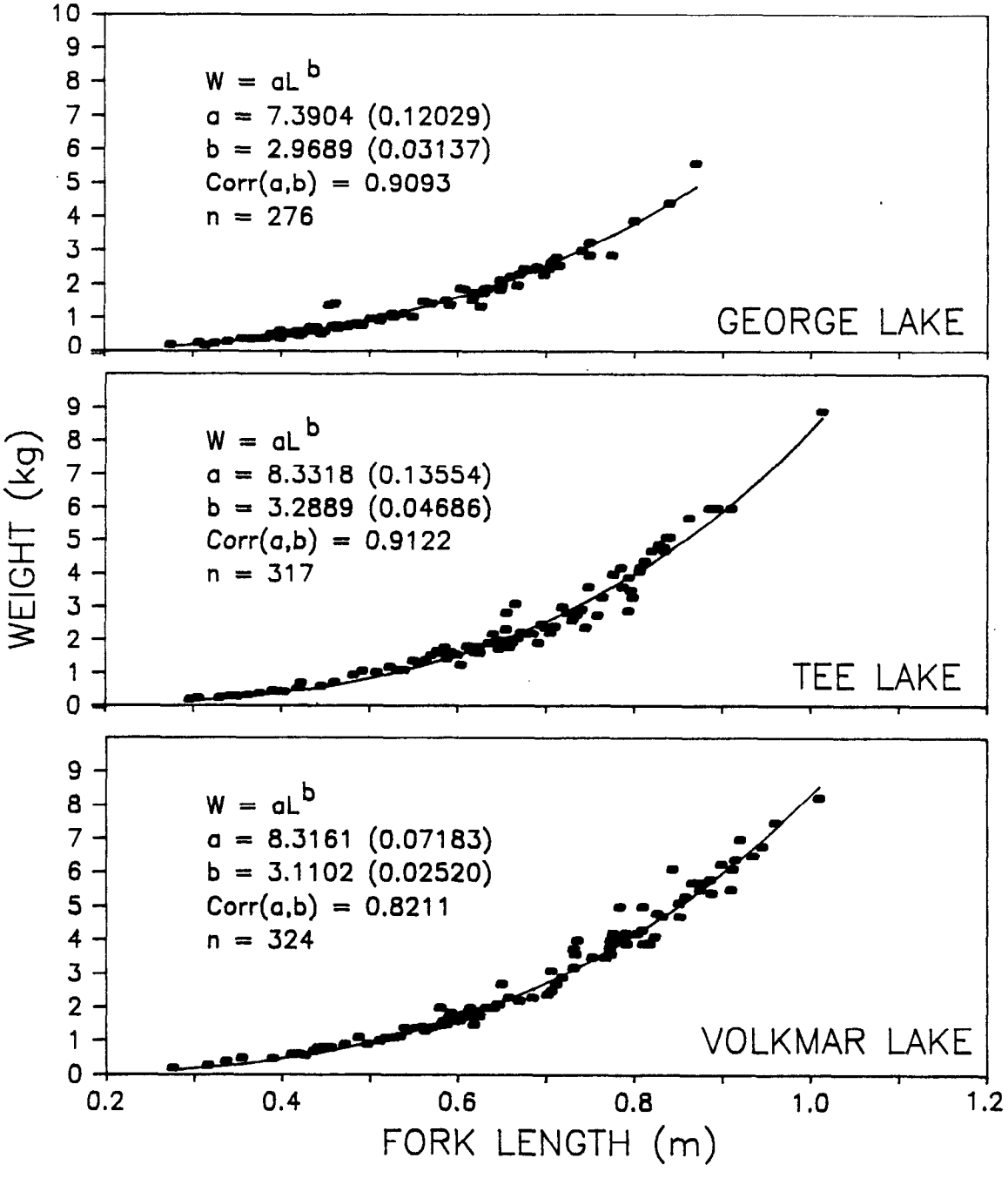

Figure 3. Length-weight relationships for northern pike populations in Tee, George, and Volkmar Lakes. Standard errors of estimated parameters are in parentheses.

Lakes, respectively, the oldest were 10 and 9 years old. Estimates of mean length at age for northern pike in George, Volkmar, and Tee Lakes are in Appendix Tables 8 and 9.

The parameters for length-at-age relationships of northern pike (sexes combined) in George and Tee Lakes were estimated (Figure 4). All available data were used for Tee Lake. For George Lake, however, 20 percent of the data of fish age 3 through 6 were randomly selected for the analysis; all data on the remaining ages were used. Inspection of the data revealed no significant differences in the length-at-age relationships for males and females in any either of these two lakes.

The length-at-age relationships for males and for females are shown separately for the population in Volkmar Lake (Figure 5) because females grow to a larger asymptotic length than do males after age 4. All data were used in these analyses.

Weight-At-Age Relationship:

Parameters for the von Bertalanffy weight-at-age relationships are the same as those for the length-at-age and length-weight relationships with one exception. The asymptotic weight is the asymptotic length transformed through the length-weight relationship. The asymptotic weights for northern pike in George and Tee Lakes were 14.233 and 7.360 kg, respectively. The asymptotic weights for male and female northern pike in Volkmar Lake were 3.020 and 14.473 kg, respectively.

Length Frequency and Sex Composition:

The length frequency for northern pike males and females captured in late May and early June in George Lake was tabulated (Figure 6). Males were predominant in most length groups up to 449 mm FL. Both sexes were equally represented in the 450-499 mm FL group, and females were predominant in groups above 500 mm FL. All fish 700 mm FL long and larger were females.

In Tee Lake, males were predominant up to 649 mm FL while most of the larger northern pike in the sample were females (Figure 6). Most of the pike greater than 650 mm and all greater than 750 mm were females.

Males were predominant in the samples from Volkmar Lake up through the 550-599 mm FL group, and females were predominant at larger lengths (Figure 6). All pike 800 mm FL long and longer were females.

The sex composition of northern pike populations in Tee, Volkmar, and George Lakes for 1986 was calculated after adjustment of raw data for gear selectivity (Table 10). The proportion of females in each population was estimated for small ($\leq$ 450 mm FL), medium (450-749 mm FL), and large fish ($\geq$ 750 mm FL). The sex ratios from the samples of medium-sized and large fish were weighted by abundance estimates for these size groups (small fish were not completely recruited to the sampling gear). Because there were no abundance estimates for George Lake, there was no adjustment for that population.

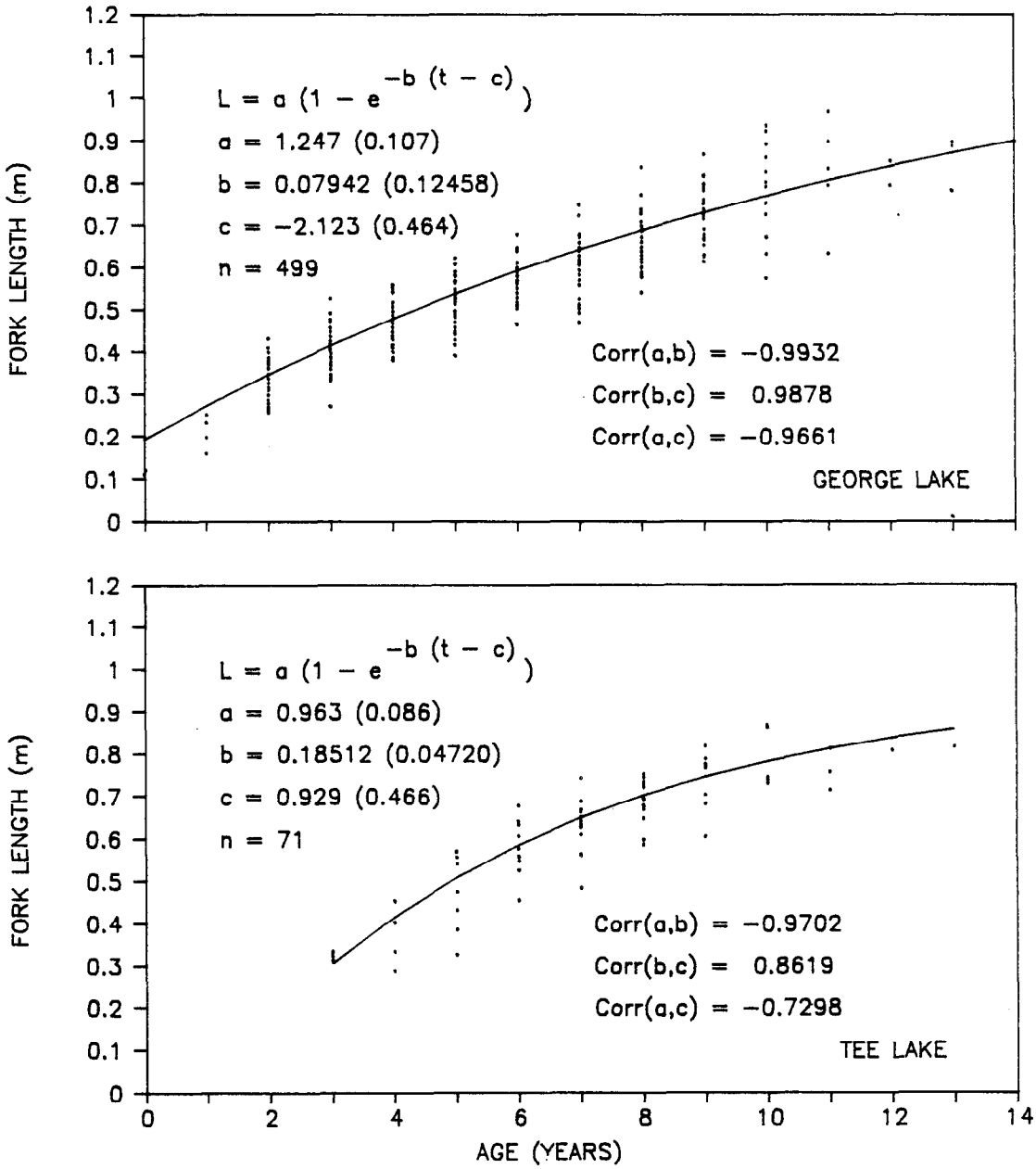

Figure 4. Length-at-age relationships for northern pike populations in George and Tee Lakes. Values in parentheses following parameter estimates are the standard errors.

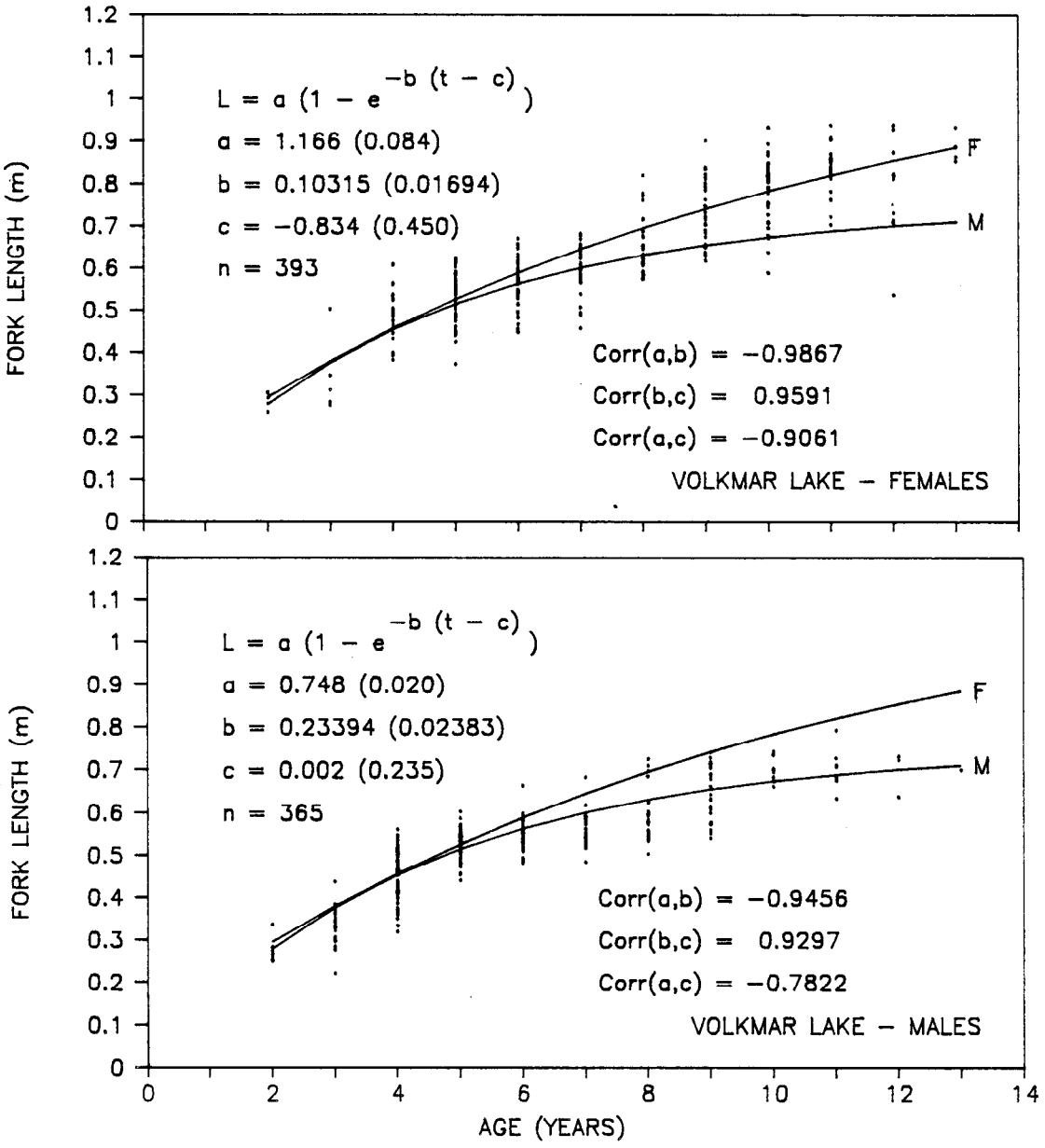

Figure 5. Length-at-age relationships for males and females in the northern pike population in Volkmar Lake. Values in parentheses following parameter estimates are the standard errors.

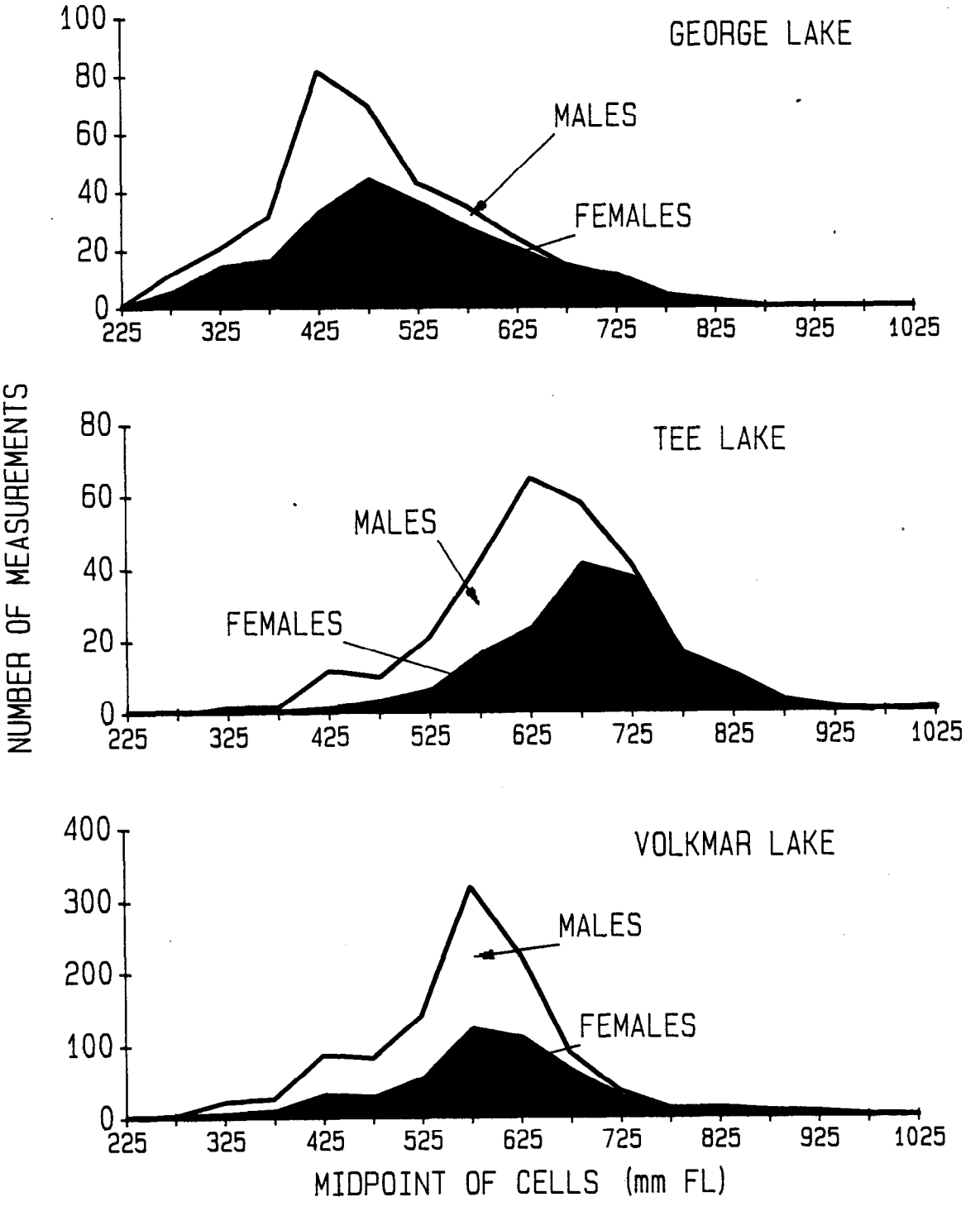

Figure 6. Length frequency by sex of northern pike sampled in George, Volkmar, and Tee Lakes during 1986.

Table 10. Sex composition for northern pike populations in Tee, Volkmar, and George Lakes in 1986 with adjustment for gear selectivity for medium-sized (450-749 mm FL) and larger fish in Tee and Volkmar Lakes.[1]

	Northern Pike by Size Class			
Category	Small	Medium	Large	All Fish
TEE LAKE				
Sample Size	13	270	32	315
No. Females	1	139	32	
Percent Females	7.7	51.5	100.0	56.0
SE % Females	7.7	3.0	0.0	
Abundance		412	42	454
VOLKMAR LAKE				
Sample Size	146	899	43	1,088
No. Females	44	401	37	
Percent Females	30.1	44.6	86.0	46.0
SE % Females	3.8	1.7	5.3	
Abundance	3,556	3,890	136	4,026
GEORGE LAKE				
Sample Size	147	198	6	351
No. Females	67	151	6	224
Percent Females	45.6	76.3	100.0	
SE % Females	4.1	3.0	0.0	

[1] Small fish were shorter than 450 mm FL, medium fish were 450-749 mm FL, and large fish were longer than 749 mm FL.

Females comprised a lesser percentage of small northern pike in Tee Lake than in Volkmar or George lakes. In Tee Lake, females comprised 7.7% of the small, 51.5% of the medium, and 100% of the large northern pike in the population. In Volkmar Lake, females comprised 30.1% of small, 44.6% of medium, and 86.0% of large northern pike in the population. In George Lake, females accounted for 45.6% of small, 76.3% of medium, and 100% of the large northern pike in the sample.

Growth:

Growth of northern pike in Volkmar Lake was determined from recaptured fish during sampling in 1985 and 1986. Recaptures in 1985 were from limited tagging in 1983 and 1984 (n = 101). Recaptures in 1986 were mostly from fish tagged in 1985 (n = 971), but also included a few from 1983 and 1984. Several fish tagged in 1983 and 1984 were recaptured in 1985 and again in 1986. Growth in mm per month and mm per year was determined separately for 112 male and 112 female northern pike (Tables 11 and 12, respectively). The categories represent the fork length of the fish at the time of tagging. A comparison of the mean growth in each of the 50 mm categories from 300 to 700 mm FL shows that females grew faster than males in every size range. The largest males were in the 700-749 mm FL group, while the largest female was in the 950-999 mm FL category. The loss of 30 mm of length (from 990 mm in June 1985 to 960 mm in June 1986) by a single fish was probably due to measurement or recording error.

Gear Assessment

Of the three gears used in Volkmar and George Lakes in 1986, seines produced the highest CPUE and the lowest mortality rates of northern pike (Table 13). Seining was most effective in George Lake during 11-13 June, about 10 days after the lake became ice free. Although northern pike were still plentiful in the shallows, spawning had probably been completed for at least a week. As many as 126 northern pike were captured in a single seine haul with a 67 m (220 ft) bag seine. The average CPUE for the 67 m seine was 122.3 northern pike per hour for five hauls. The largest CPUE for a single haul with a 30 m (100 ft) seine was 52.8 per hour.[1] Sets of trap nets on George Lake during this time were Types B and E shown in Figure 2. The average CPUE for seven trap nets fished in June was only 0.9 northern pike per hour.[2] The most effective set was a single Type B which captured 102 northern pike in three nights, with a high catch of 68 in one overnight set. All of the fish were caught in the outside trap. However, location of the set might have been more responsible for the good catches than the type of set. This particular set was off a point at the entrance of a small, shallow bay with known concentrations of northern pike (known from seining in the bay). The 34 m (110 ft) center lead blocked about half of the entrance to the bay.

[1] Effort for a seine haul was the time in hours from first wetting the net until it had been completely pulled ashore.

[2] Effort for a set with a trap net was the time in hours between consecutive visits to the set.

Table 11. Average growth of male northern pike in Volkmar Lake as estimated from multiple measurements of individual fish between 1985 and 1986.

Length Categories (FL in mm)	Number of Pike	Growth in mm			
		Monthly		Annual	
		Mean	SE	Mean	SE
300 - 349	1	7.7		92	
350 - 399	3	3.1	0.4	37	5.4
400 - 449	8	4.1	0.3	50	4.0
450 - 499	15	2.6	0.5	31	5.8
500 - 549	29	2.6	0.2	31	2.8
550 - 599	36	2.6	0.3	31	3.7
600 - 649	12	2.6	0.5	31	6.0
650 - 699	4	1.5	0.8	18	9.1
700 - 749	4	1.2	0.6	14	7.2

Table 12. Average growth of female northern pike in Volkmar Lake as estimated from multiple measurements of individual fish between 1985 and 1986.

Length Categories (FL in mm)	Number of Pike	Growth in mm			
		Monthly		Annual	
		Mean	SE	Mean	SE
300 - 349	1	8.9		107	
350 - 399	1	4.8		57	
400 - 449	1	4.9		59	
450 - 499	5	4.1	0.5	49	5.5
500 - 549	15	4.2	0.5	50	5.5
550 - 599	36	3.4	0.3	40	3.4
600 - 649	23	3.5	0.4	42	4.8
650 - 699	12	2.6	0.7	31	8.6
700 - 749	3	3.8	1.1	45	12.8
750 - 799	0				
800 - 849	7	2.0	0.5	24	6.0
850 - 899	5	1.4	0.2	17	2.8
900 - 949	2	2.1	0.5	26	5.9
950 - 999	1	-2.5		-30	

Table 13. Average Catch Per Unit of Effort (CPUE) and mortality rates of northern pike caught in trap nets, gill nets, and seines used in Volkmar and George Lakes in 1986.

	Seines[1]			Trap	Gill[2]
	30 m	67 m	All	Nets	Nets
GEORGE LAKE - Early (11-13 June)					
Average	52.8	122.3	108.4	0.9	6.1
SE	_	38.4	33.1	0.4	2.8
Mortality Rate	0.0%	0.0%	0.0%	8.7%	6.1%
VOLKMAR LAKE Later (16-19 June)					
Average	30.7	9.4	26.1	1.2	2.8
SE	9.9	3.2	7.5	0.3	0.5
Mortality Rate	0.0%	0.0%	0.0%	15.3%	25.8%
GEORGE LAKE Late (20-21 August)					
Average	0.0	5.0	3.8	0.2	
SE	-	2.5	3.2	0.1	
Mortality Rate	0.0%	0.0%	0.0%	55.6%	

[1] No fish were caught in the 30 x 4.25 m bagless seine.
[2] Only six-panel gill nets were used.

In four net nights, only four northern pike were captured with Type E sets. Six sets were made with gill nets for an average CPUE of 6.1 fish per hour. During the second sampling event on Volkmar Lake from June 16-19, water temperatures had warmed considerably since early June, and northern pike were not as plentiful in shallow water as they had been during the first sampling event when only gill nets had been used to capture fish.

Five hauls were made with a 67 m seine and 19 hauls were made with a 30 meter seine. The 30 m seine had a higher CPUE of 30.7 per hour as compared to 9.4 northern pike per hour with a 67 m seine. The average CPUE for 13 trap nets of Types A, B, C, and D was 1.2 per hour. The highest overnight catch in a single trap was 12 northern pike. Fifty-three sets were made with gill nets resulting in an average CPUE of 2.8 fish per hour.

Sampling George Lake in August with seines and trap nets met with poor success. Six sets with Types E and F trap nets had an average CPUE of 0.2 fish per hour. Also, northern pike were scarce in areas that could be effectively seined. Some northern pike were seined in and near areas of dense aquatic vegetation, but difficulty was encountered in pulling the seine and keeping the lead line near the bottom.

No northern pike were killed during seining operations in either lake; in contrast, northern pike caught in trap and gill nets in Volkmar Lake in mid-June had mortality rates of 15.3% and 25.8%, respectively. During August, northern pike caught in seines suffered no mortality while five of the nine caught in trap nets died, mostly because small northern pike (270-350 mm FL) were gilled in the 25 mm mesh of the center lead and trap.

DISCUSSION

Both estimates of the abundance in Volkmar Lake of northern pike longer than 450 mm FL (4,027 and 3,997) compare closely with the estimate of 4,020 from 1985 (Peckham 1986). However, the estimate for northern pike $\geq$ 750 mm FL was 136 for 1986, a substantial difference from the estimate of 405 pike $\geq$ 700 mm FL for 1985. Also, northern pike $\geq$ 750 mm FL comprised 12.3% of the total sample in 1985 (n = 1,168) as compared to 3.3% in 1986 (n = 1,511). And northern pike $\geq$ 700 mm FL comprised 18.2% of the sample in 1985 compared to 6.4% in 1986. The reduction in numbers of fish in the larger size groups is probably due in part to known and delayed mortality from gillnetting and handling in 1985. However, changes in sampling gear from five-panel gill nets in 1985 to mostly six-panel gill nets with smaller mesh, to trap nets, and to seines would have reduced the number of large fish in the sample in 1986. Increased winter harvest by anglers is no doubt also a contributing factor.

Tee Lake has a larger fraction of its population composed of big fish ($\geq$ 750 mm FL) than either Volkmar or George Lakes. The use of trap nets and seines in George and not in Tee Lake could be the reason for this difference in sizes in the samples, however, estimates of abundance are available for both Tee and Volkmar Lakes. The difference between these two lakes could be because of differences in genetics, previous sampling with

gill nets in Volkmar Lake with high sampling-induced mortality rates, or due to the greater access and popularity of Volkmar Lake as a sport fishery for northern pike.

The five-panel variable mesh gill nets were not as effective in catching fish as were the six-panel nets. The former were of course shorter, but the analysis of catchability coefficients showed that the panel with the 76 mm mesh is ineffective and the panel with 64 mm mesh catches almost exclusively large fish. The six-panel nets do not have panels with these larger meshes. In the future, the six-panel experimental nets should be used in these lakes or in lakes with northern pike populations with similar length frequencies.

Although Volkmar Lake has about twice the surface area of Tee Lake, it has about ten times as many northern pike. Also, Tee Lake has the "fatter" fish and the fish with the faster growth. Tee Lake is the smallest and the deepest of the three lakes in this study. The most likely reason for differences in abundance between Tee and Volkmar Lakes is a lack of spawning or rearing habitat in the former lake. The fewer young northern pike that survive in Tee Lake most likely find ample food with little competition.

Enough data have been collected to adequately describe the length-at-age relationships for northern pike in George Lake and for female northern pike in Volkmar Lake; more data are needed on males in Volkmar Lake and for both sexes of northern pike in Tee Lake. The situation of different growth rates for the two sexes in Volkmar Lake is typical of populations far to the south (see Carlander 1969); the similar growth rates for both sexes observed for the population in George Lake is more typical of northern pike in northern Canada. The predominance of older, larger females in the populations of these three lakes is also typical of populations of northern pike throughout their range. However, the low asymptotic weights and few data from Tee Lake indicate that more data, especially from older fish, are needed to better describe the relationship. For the population of males in Volkmar Lake, length-at-age "levels off" after age 8 which "draws" the estimated asymptotic length below some observed lengths; more data are needed on older males to see if this situation is a phenomenon of sampling. If there are no older males in either Tee or Volkmar Lakes, then some other model of growth is needed.

Seines were the obvious winner in the gear contest; more fish were caught and released in seines than either gill nets or trap nets. Seines proved labor intensive, but so did gill nets when monitored constantly to minimize mortality of captured northern pike. The more passive nature of trap nets would allow their operation while personnel concentrate on seines. However, the low catch rates with traps precludes sole reliance on them as sampling gear.

Although seines showed the most promise as an effective gear to capture northern pike, the seining in 1986 was largely experimental and certain modifications of the gear are planned for future work to provide greater effectiveness and efficiency. If known areas of extreme muck bottom are

avoided, the 67 x 3 m bag seine with 25 mm bar mesh is a practical size to use with a three- or four-man crew. The seine is stacked on the bow of a boat and fed out while motoring in reverse in a semi-circle. Approximately 30 m of rope on each end allows for coverage of a larger area. The most effective way to use seines is to use them early just after the lake becomes ice-free; northern pike are in the shallows at that time, and there is less vegetation then to hamper movement of the seine.

No gear was effective in catching northern pike after the middle of June. The sampling rate dropped in all waters for the second sampling event. The optimal time to catch northern pike in either Volkmar or George Lake is immediately after the ice has left the lake when water temperatures are cool, the fish are in the shallows, and submerged vegetation is sparse. The speed at which the sampling rate dropped from the first to the middle of June in Volkmar Lake shows that the time for catching lots of northern pike with relatively little fishing effort is extremely short.

ACKNOWLEDGEMENTS

Thanks are due to Sandy Sonnichsen for assistance with analysis concerning abundance estimates. Thanks are due to Gary Pearse for logistic support, and Rolland Holmes, Fred DeCicco, Gary Pearse, James Parker, Al Mathews, Matt Evenson, Jared Baker, Mark Ross, and Dave Waldo for assistance with field work. Thanks are due to Richard Logan for providing encouragement, direction, and partial funding for the study. Thanks are due to the U.S. Fish and Wildlife Service for providing partial funding for this project.

LITERATURE CITED

Carlander, K. D. 1969. Handbook of freshwater fisheries biology, Volume I, 3rd ed. Iowa State University Press, Ames, Iowa. 752 p.

Casselman, J. M. 1974. External sex determination of northern pike, *Esox lucius* Linnaeus. Trans. Amer. Fish. Soc. 103(2):343-347.

Efron, B. 1982. The jackknife, bootstrap, and other resampling plans. Society of Industrial Applied Mathematics Monograph No. 38. 92 p.

Hamley, J. H. 1975. Review of gill net selectivity. J. Fish. Res. Board Can. 32(11):1943-1969.

Marquardt, D. W. 1960. An algorithm for least-squares estimation of non-linear parameters. J. Society of Industrial and Applied Mathematics 11:431-441.

Mills, M. J. 1986. Alaska statewide sport fish harvest studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-86, Project F-10-1, 27(RT): 1-137.

Peckham, Richard D. 1972. Inventory and cataloging of the sport fish and sport fish waters in Interior Alaska. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1971-1972, Proj. F-9-4, 13(G-I-G): 111-128.

_____. 1973. Evaluation of Interior Alaska waters and sport fish with emphasis on stocked lakes. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1972-1973, Project F-9-5, 14(G-III-E): 18-47.

_____. 1974. Evaluation of Interior Alaska waters and sport fish with emphasis on stocked lakes. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1973-1974, Project F-9-6, 15(G-III-E): 1-38.

_____. 1975. Evaluation of Interior Alaska waters and sport fish with emphasis on stocked lakes. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1974-1975, Project F-9-7, 16(G-III-E): 52-77.

_____. 1976. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1975-1976, Project F-9-8, 17(G-III-I): 31-50.

_____. 1977. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1976-1977, Project F-9-9, 18(G-III-I): 88-105.

_____. 1978. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual report of Progress, 1977-1978, Project F-9-10, 19(G-III-I): 63-82.

_____. 1979. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1978-1979, Project F-9-11, 20(G-III-I): 87-114.

_____. 1980. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1979-1980, Project F-9-12, 21(G-III-I): 1-25.

_____. 1981. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1980-1981, Project F-9-13, 22(G-III-I): 1-37.

_____. 1982. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual report of Progress, 1981-1982, Project F-9-14, 23(G-III-I). 1-28.

_____. 1983. Evaluation of Interior Alaska waters and sport fish with emphasis on managed water - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1982-1983, Project F-9-15, 24(G-III-I): 1-38.

_____. 1984. Evaluation of Interior Alaska waters and sport fish with emphasis on managed waters - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1983-1984, Project F-9-16, 25(G-III-I): 1-25.

_____. 1985. Evaluation of Interior Alaska waters and sport fish with emphasis on managed waters - Delta District. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1984-1985, Project F-9-17, 26(G-III-I): 27-66.

_____. 1986. Interior Alaska (Tanana Drainage) northern pike studies. Alaska Department of Fish and Game. Federal Aid in Fish Restoration, Annual Report of Progress, 1985-1986, Project F-10-1, 27(N-8-2): 83-103.

Ricker, W. E. 1975. Computation and interpretation of biological statistics of fish populations. Fisheries Research Board of Canada, Bulletin No. 191. 382 p.

APPENDICES

Appendix Table 1. Analysis of variance table for comparison of annuli counts from vertebra, cleithra, and scales.[1,2]

Source	DF	SS	MS	F Ratio	F Value	α
Model (M)	350	17,735	51	M/E	104.1	<0.0001
Fish (F)	38	16,854	444			
Reader (R)	2	163	81	R/RSF	39.0	<0.0001
Structure (S)	2	28	14	S/RS	1.0	0.4465
RS	4	56	14	RS/RSF	6.7	<0.0001
RSF	304	635	2			
Sampling Error (E)	585	285				
Corrected Total (T)	935	18,020				

Reader[3]	1	2	3
Mean	6.26	6.01	6.67

Structure	Vertebra	Cleithra	Scales
Mean	6.60	6.32	6.19

[1] Experimental design is based on an unbalanced general linear model with structures as fixed effects and readers as random effects.
[2] Samples were taken from Volkmar Lake in 1985 and 1986.
[3] Multiple comparisons are based on least significant differences with $\alpha = 0.05$; means or groups of means not connected by line represent significantly different counts between the corresponding readers or structures.

Appendix Table 2. Number of northern pike captured in gill nets, trap nets, and seines in Volkmar Lake, 16-19 June 1986.

	Length (mm FL)			
	300-399	400-499	500-599	≥ 600
Gill Nets	33	41	74	78
Seines	66	39	40	20
Trap Nets	23	9	22	14
	$\chi^2 = 50.37$[1]	$P < 0.001$		$df = 6$

[1] The χ^2 value is the test statistic for the hypothesis of equal probability of capture among gear for fish of different lengths.

Appendix Table 3. Numbers of northern pike tagged in Volkmar Lake 3-6 June then recaptured 16-19 June 1986, with gill nets.

	Length (mm FL)		
	450-549	550-649	≥ 650
Recaptured	5	16	12
Not Recaptured	203	461	123
	$\chi^2 = 10.24$[1]	$0.005 < P < 0.01$	df = 2

[1] The χ^2 value is the test statistic for the hypothesis of equal probability of capture of fish of different lengths.

Appendix Table 4. Numbers of northern pike tagged in Tee Lake 30 May-1 June then recaptured 11-13 June with gill nets in 1986.

	Length (mm FL)			
	450-549	550-649	650-749	≥ 750
Recaptured	4	24	15	12
Not Recaptured	29	81	79	15
	$\chi^2 = 12.06$[1]	$0.005 < P < 0.01$		df = 3

[1] The χ^2 value is the test statistic for the hypothesis of equal probability of capture of fish of different lengths.

Appendix Table 5. Numbers of tagged northern pike released 30 May-1 June and recovered in Tee Lake, 11-13 June by area in 1986.

Area of Release	Area of Recovery A	Area of Recovery B	Not Recaptured
Tagged in A	9	14	139
Tagged in B	14	10	93

$\chi^2 = 3.58$[1] $0.10 < P < 0.25$ $df = 2$

[1] The following χ^2 value is the test statistic for the hypothesis of equal probability of capturing fish in either half of Tee Lake.

Appendix Table 6. Standard errors for the average Catch Per Unit of Effort (CPUE) and catchability coefficients (q) by panel in five- and six panel gill nets fished in Volkmar Lake for northern pike 3-6 June 1986.[1]

	25 mm mesh			38 mm mesh			
	Small[2]	Medium	Large	Small	Medium	Large	Hours Fished
5-Panel	0.058	0.035	0.000	0.000	0.079	0.011	79.7
6-Panel	0.016	0.040	0.004	0.022	0.093	0.008	533.5
CPUE	0.019	0.032	0.003	0.017	0.073	0.007	346.5
$qx10^5$	1.430	0.472	1.982	1.313	3.268	6.189	

	51 mm mesh			64 mm mesh			
	Small	Medium	Large	Small	Medium	Large	Hours Fished
5-Panel	0.000	0.094	0.016	0.014	0.022	0.047	79.7
6-Panel	0.004	0.071	0.013				533.5
CPUE	0.003	0.059	0.011	0.014	0.022	0.047	346.5[3]
$qx10^5$	0.076	2.343	16.272	0.423	0.593	48.790	

[1] All five-panel nets were floating gill nets; six-panel nets were both sinking and floating.

[2] Small fish were shorter than 450 mm FL, medium fish were 450-749 mm FL, and large fish were longer than 749 mm FL.

[3] The hours for the six-panel nets were halved from 533.5 to 266.7 for the weights because each hour that one of these nets was fished, two panels of each mesh size were in the water.

Appendix Table 7. Standard errors of average Catch Per Unit of Effort (CPUE) and catchability coefficients (q) by panel in five- and six-panel gill nets fished in Tee Lake for northern pike 30 May-1 June 1986.[1]

	25 mm mesh			38 mm mesh			
	Small[2]	Medium	Large	Small	Medium	Large	Hours Fished
5-Panel	0.000	0.198	0.000	0.000	0.063	0.000	5.6
6-Panel	0.011	0.020	0.004	0.014	0.043	0.011	289.5
CPUE	0.010	0.021	0.003	0.011	0.041	0.010	150.4
$qx10^5$		5.409	0.830		12.190	24.923	

	51 mm mesh			64 mm mesh			
	Small	Medium	Large	Small	Medium	Large	Hours Fished
5-Panel	0.000	0.026	0.026	0.000	0.000	0.026	5.6
6-Panel	0.002	0.043	0.018				289.5
CPUE	0.002	0.041	0.017			0.026	150.4[3]
$qx10^5$		12.357	43.794			61.970	

[1] All five-panel nets were floating gill nets; six-panel nets were both sinking and floating.

[2] Small fish were shorter than 450 mm FL, medium fish were 450-749 mm FL, and large fish were longer than 749 mm FL.

[3] The hours for the six-panel nets were halved from 289.5 to 144.8 for the weights because each hour that one of these nets was fished, two panels of each mesh size were in the water.

Appendix Table 8. Mean length at age for male northern pike from George, Volkmar, and Tee Lakes.[1,2]

	George Lake			Tee Lake			Volkmar Lake		
Age	Sample Size	Mean	SE	Sample Size	Mean	SE	Sample Size	Mean	SE
1	2	260	9						
2	7	303	7				11	287	7
3	17	426	7	3	340	6	28	352	8
4	19	467	9	4	387	37	76	465	7
5	15	509	12	5	495	51	63	542	4
6	6	555	19	5	577	31	37	562	6
7	5	542	20	7	611	24	29	572	7
8	4	618	23	6	675	25	30	599	10
9	1	809		1	621		28	664	12
10				1	747		12	713	10
11							9	719	15
12							4	722	23
13							1	716	
14									
	76			32			328		

[1] Data for the population in George Lake were collected in 1972, 1974-6, 1979-81, and 1986; for the population in Volkmar Lake in 1985-6; and for the population in Tee Lake in 1986.

[2] Measurements are in mm FL.

Appendix Table 9. Mean length at age for female northern pike from George, Volkmar, and Tee Lakes.[1,2]

	George Lake			Tee Lake			Volkmar Lake		
Age	Sample Size	Mean	SE	Sample Size	Mean	SE	Sample Size	Mean	SE
1									
2	4	302	16				6	301	9
3	12	421	14				12	323	19
4	14	485	12				29	513	10
5	13	551	16	2	511	63	60	548	7
6	19	604	9	5	613	28	48	580	9
7	13	661	12	6	677	19	38	609	8
8	14	682	14	7	727	12	33	664	11
9	10	718	26	7	775	18	31	755	14
10	4	779	33	4	821	36	45	810	10
11	3	829	97	2	752	22	24	843	12
12	1	812					13	813	29
13	1	914		1	834		6	896	12
14							1	912	
	108			34			346		

[1] Data for the population in George Lake were collected in 1972, 1974-6, 1979-81, and 1986; for the population in Volkmar Lake in 1985-6; and for the population in Tee Lake in 1986.

[2] Measurements are in mm FL.